International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN 2249-6890
Vol. 3, Issue 5, Dec 2013, 61-72

TEACHER LEARNING BASED OPTIMIZATION OF ASSIGNMENT MODEL

SONAL RAI, SANTOSH KU. MISHRA & MUKESH DUBEY

Department of Mechanical Engineering, Bhilai Institute of Technology, Durg, Chhattisgarh, India

ABSTRACT

A new efficient optimization method, called 'Teaching–Learning-Based Optimization (TLBO)', is proposed in this paper for the optimization of mechanical design problems. This method works on the effect of influence of a teacher on learners. Like other nature-inspired algorithms, TLBO is also a population-based method and uses a population of solutions to proceed to the global solution. The population is considered as a group of learners or a class of learners. The process of TLBO is divided into two parts: the first part consists of the 'Teacher Phase' and the second part consists of the 'Learner Phase'. 'Teacher Phase' means learning from the teacher and 'Learner Phase' means learning by the interaction between learners. The basic philosophy of the TLBO method is explained in detail. To check the effectiveness of this method it is tested on four different models with different characteristic. The effectiveness is compared with assignment model. Results show better result with reduced confusion of assignment.

KEYWORDS: Teaching Learning Based Optimization, Assignment Model, Optimization

INTRODUCTION

Teaching–Learning-Based Optimization

TLBO algorithm is a teaching–learning process inspired algorithm proposed by Rao et al. (2011 & 2012), which is based on the effect of influence of a teacher on the output of learners in a class. The algorithm mimics the teaching–learning ability of teacher and learners in a class room. Teacher and learners are the two vital components of the algorithm and describes two basic modes of the learning, through teacher (known as teacher phase) and interacting with the other learners (known as learner phase). The output in TLBO algorithm is considered in terms of results or grades of the learners which depend on the quality of teacher. So, teacher is usually considered as a highly learned person who trains learners so that they can have better results in terms of their marks or grades. Moreover, learners also learn from the interaction among themselves which also helps in improving their results. TLBO is a population based method. In this optimization algorithm, a group of learners is considered as population and different design variables are considered as different subjects offered to the learners and learners' result is analogous to the "fitness" value of the optimization problem. In the entire population the best solution is considered as the teacher. The working of TLBO is divided into two parts, "Teacher phase" and "Learner phase". Working of both the phases is explained below.

Teacher Phase

Assume two different teachers, T_1 and T_2, teaching a subject with same content to the same merit level learners in two different classes. Figure 1 shows the distribution of marks obtained by the learners of two different classes evaluated by the teachers. Curves 1 and 2 represent the marks obtained by the learners taught by teacher T_1 and T_2 respectively. A normal distribution is assumed for the obtained marks, but in actual practice it can have skewness. Normal distribution is defined as,

$$f(X) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-(X-\mu)^2}{2\sigma^2}} \tag{1}$$

Where σ^2 is the variance, μ is the mean and x is any value of which normal distribution function is required.

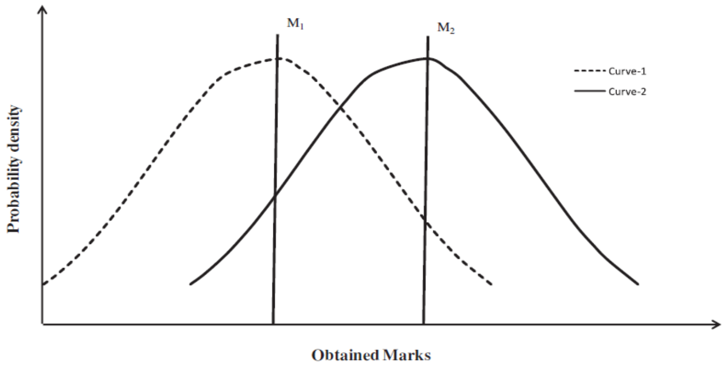

Figure 1: Distribution of Marks Obtained by Learners Taught by Two Different Teachers

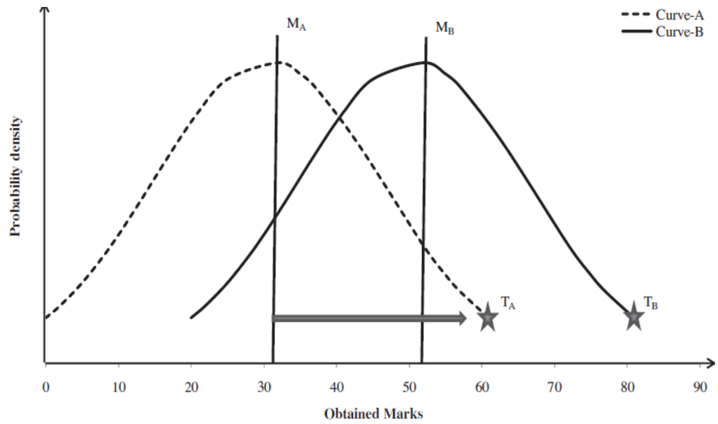

Figure 2: Model for Obtained Marks Distribution for a Group of Learners

As shown in Figure 2, the mean of a class increases from M_A to M_B depending upon a good teacher. A good teacher is one who brings his or her learners up to his or her level in terms of knowledge. But in practice this is not possible and a teacher can only move the mean of class up to some extent depending on the capability of the class. This follows a random process depending on many factors. Let M_i be the mean and T_i be the teacher at any iteration i. T_i will try to move mean M_i towards its own level, so now the new mean will be T_i designated as M_{new}. The solution is updated according to the difference between the existing and the new mean given by

$$\text{Difference\_Mean}_i = r_i\,(M_{new} - T_F M_i) \tag{2}$$

Where T_F is a teaching factor that decides the value of mean to be changed, and r_i is a random number in the range [0, 1]. The value of T_F can be either 1 or 2, which is again a heuristic step and decided randomly with equal probability as

$$T_F = \text{round}\,[1 + \text{rand}\,(0, 1)\,\{2 - 1\}].$$

This difference modifies the existing solution according to the following expression

$$X_{new,i} = X_{old,i} + \text{Difference\_Mean}_i \tag{3}$$

Learner Phase

Learners increase their knowledge by two different means: one through input from the teacher and the other through interaction between themselves. A learner interacts randomly with other learners with the help of group discussions, presentations, formal communications, etc. A learner learns something new if the other learner has more knowledge than him or her. Learner modification is expressed as,

For i = 1 : P_n

Randomly select two learners Xi and Xj, where i ≠ j

If f (X_i) < f (X_j)

$X_{new,}\, i = X_{old,}\, i + r_i\,(X_i - X_j)$

Else

$X_{new,}\, i = X_{old,}\, i + r_i\,(X_j - X_i)$

End If

End For

Accept X_{new} if it gives a better function value.

IMPLEMENTATION OF TLBO FOR ASSIGNMENT PROBLEM OPTIMIZATION

The step-wise procedure for the implementation of TLBO is given in this section.

Step 1: Define the optimization problem and initialize the optimization parameters.

Initialize the population size (P_n), number of generations (G_n), number of design variables (D_n), and limits of design variables (U_L, L_L).

Define the optimization problem as:

Minimize f(X).

Subject to $X_i \in x_i = 1, 2. . . D_n$

where f(X) is the objective function, X is a vector for design variables

such that $L_{L,i} \leq x_{,I} \leq U_{L,I}$.

Step 2: Initialize the population.

Generate a random population according to the population size and number of design variables. For TLBO, the population size indicates the number of learners and the design variables indicate the subjects (i.e. courses) offered. This population is expressed as

$$\text{Population} = \begin{bmatrix} x_{1,1} & x_{1,2} & \cdot & \cdot & \cdot & x_{1,D} \\ x_{2,1} & x_{2,2} & \cdot & \cdot & \cdot & x_{2,D} \\ & & & \cdot & \cdot & \\ \cdot & \cdot & & & & \cdot \\ \cdot & \cdot & & & & \cdot \\ x_{Pn,1} & x_{Pn,2} & \cdot & \cdot & & x_{Pn,D} \end{bmatrix}$$

Step 3: Teacher phase.

Calculate the mean of the population column-wise, which will give the mean for the particular subject as

$$M_{,D} = [m_1, m_2, \ldots, m_D]. \tag{4}$$

The best solution will act as a teacher for that iteration

$X_{teacher} = X_{f(X)=min}$. (5)

The teacher will try to shift the mean from $M,_D$ towards $X,_{teacher}$, which will act as a new mean for the iteration. So,

$M\_new,_D = X_{teacher,D}$. (6)

The difference between two means is expressed as

$Difference,_D = r\ (M\_new,_D - T_F M,_D)$. (7)

The value of TF is selected as 1 or 2. The obtained difference is added to the current solution to update its values using

$X_{new,D} = X_{old,D} + Difference,_D$. (8)

Accept X_{new} if it gives better function value.

Step 4: Learner phase.

As explained above, learners increase their knowledge with the help of their mutual interaction. The mathematical expression is explained in learner's phase

Step 5: Termination criterion.

Stop if the maximum generation number is achieved; otherwise repeat from Step 3.

It is seen from the above steps that no provision is made to handle the constraints in the problem. Many types of constraint handling technique are available in the literature, such as incorporation of static penalties, dynamic penalties, adaptive penalties etc. Deb's heuristic constrained handling method [12] is used in the proposed TLBO method. This method uses a tournament selection operator in which two solutions are selected and compared with each other. The following three heuristic rules are implemented on them for the selection:

- If one solution is feasible and the other infeasible, then the feasible solution is preferred.
- If both the solutions are feasible, then the solution having the better objective function value is preferred.
- If both the solutions are infeasible, then the solution having the least constraint violation is preferred.

These rules are implemented at the end of Steps 2 and 3, i.e. at the end of the teacher phase and the learner phase. Instead of accepting solution X_{new}, if it gives better function value at the end of Steps 2 and 3, Deb's constraint handling rules are used to select X_{new} based on the three heuristic rules.

COMPARISION OF TLBO WITH OTHER OPTIMIZATION TECHNIQUE

Like Genetic algorithm (GA) (Goldberg D. Genetic algorithms Addison-Wesley; 1989), Particle Swarm Optimization (PSO) (Kennedy V, Eberhart R International Conference on Neural Networks 1995, Clerc M ISTE Publishing Company; 2006)., Artificial Bee Colony(ABC)(Basturk B, Karaboga D IEEE Swarm Intelligence Symposium. 2006)., and Harmony Search(HS) (Lee KS, Geem ZW. Computer Methods in Applied Mechanics and Engineering 2004), TLBO is also a population-based technique which implements a group of solutions to proceed to the optimum solution.

Many optimization methods require algorithm parameters that affect the performance of the algorithm. GA requires the crossover probability, mutation rate, and selection method; PSO requires learning factors, the variation of

weight, and the maximum value of velocity; ABC requires the limit value; and HS requires the harmony memory consideration rate, pitch adjusting rate, and number of improvisations.

Unlike other optimization techniques TLBO does not require any algorithm parameters to be tuned, thus making the implementation of TLBO simpler. As in PSO, TLBO uses the best solution of the iteration to change the existing solution in the population, thereby increasing the convergence rate. TLBO does not divide the population like ABC. As in GA, which uses selection, crossover and mutation, and ABC, which uses employed, onlooker and scout bees, TLBO uses two different phases, the 'teacher phase' and the 'learner phase'. TLBO uses the mean value of the population to update the solution. TLBO implements greediness to accept a good solution, as in ABC.

PROBLEM STATEMENT[5]

Example 1

Prohibited Routes

Weldone Company has taken the third floor of a multi storied building for rent with a view to locate one of their zonal offices. There are five main rooms in this floor to be assigned to five managers. Each room has its own advantages and disadvantages. Some have windows; some are closer to the washrooms or to the canteen or secretion pool. The rooms are all of different sizes and shapes. each of five managers were asked to rank their room preferences amongst the rooms 301,302,303,304 and 305.Their preferences were recorded in a table as indicated below:

Table 1: Manager

M_1	M_2	M_3	M_4	M_5
302	302	303	302	301
303	304	301	305	302
304	305	304	304	304
	301	305	303	
		302		

Most of the manager did not list all the five room, since they were not satisfied with some of these rooms and they left off these rooms from list. Assuming that their preferences can be quantified by members, find our as to which manager should be assigned to which room so that their total preferences ranking is minimum.

Solution: First preparing a matrix according to their preferences

Table 2: Managers

Room No	M1	M2	M3	M4	M5
301	_	4	2	_	1
302	1	1	5	1	2
303	2	_	1	4	_
304	3	2	3	3	3
305	_	3	4	2	_

replacing (-) with "M" , and considering M as a very large number:

Table 3: Managers

Room No	M1	M2	M3	M4	M5
301	M	4	2	M	1
302	1	1	5	1	2
303	2	M	1	4	M
304	3	2	3	3	3
305	M	3	4	2	M

Now, converting it into minimization type:

Table 4: Managers

M1	M2	M3	M4	M5
M	3	1	M	0
0	0	4	0	1
1	M	0	3	M
1	0	1	1	1
M	1	2	0	M

Teacher Phase

$M_{D\,=}$ [m_1,m_2,………………m_D]

$$= \frac{0+1+1+2m}{5}, \frac{3+0+0+1+m}{5}, \frac{1+4+0+1+2}{5}, \frac{m+0+3+1+0}{5}, \frac{0+1+1+2m}{5} = [1.6]$$

M,newD = X teach,D

M - 1.6	1.4	-0.6	M	-1.6
-1.6	-1.6	2.4	-1.6	-0.6
-0.6	M	-0.6	1.4	M
-0.6	-1.6	-0.6	-0.6	-0.6
M	-1.6	0.4	-1.6	M

Since 1.6 is very much less than M (large no.) therefore their diff. M-1.6 = M

M -1.4	-0.6	M	-1.6	
-1.6 -1.6	2.4	-1.6	-0.6	
-0.6	M	-0.6	1.4	M
-0.6	-1.6	-0.6	-0.6	-0.6
M	-1.6	0.4	-1.6	M

$M_D$new = [-1.6,-1.6,-0.6,-1.6,-1.6]

= -1.6

Difference = r [$M_D$new - T_f M_D]

Assuming r= 1

= -1.6-1.6

= -3.2

Xnew = Xold,D + Diff,D

M	-0.2	-2.2	M	-3.2
-3.2	-3.2	0.8	-3.2	-2.2
-2.2	M	-3.2	-0.2	M
-2.2	-3.2	-2.2	-2.2	-2.2
M	-2.2	-1.2	-3.2	M

Learner’s Phase

By using algorithm from learner’s phase

Row I

- M > -0.2 = **M**

  M > -2.2 = M

  M = M

  M > -3.2 = M

  Since M is a very large no, therefore it difference will also be large and negligible hence, considering it as M we get,

- -0.2 < M = M

  -0.2 > -2.2 = -2.2

  -0.2< M = M

  -0.2 > -3.2 = **-3.2**

- -2.2 <M =M

  -2.2< -0.2 =**-4.2**

  -2.2 <M =M

  -2.2 >-3.2 =-3.2

- M=**M**

  M> -0.2 =M

  M> -2.2 =M

  M> -3.2 = M

- -3.2<M =M

  -3.2>-0.2 = **-6.2**

  -3.2< -2.2 = -4.2

  -3.2<M=M

Similarly applying in row II, row III, row IV, row V, comparing and selecting minimum value we,get,

$$\begin{bmatrix} M & -3.2 & -4.2 & M & -6.2 \\ -7.2 & -7.2 & -3.2 & -7.2 & -5.2 \\ -4.2 & M & -6.2 & -3.2 & M \\ -3.2 & -4.2 & -3.2 & -3.2 & -3.2 \\ M & -3.2 & -3.2 & -5.2 & M \end{bmatrix}$$

Now on assigning job to the minimum value,

Minimum ranking is = 1+1+1+2+2= **7** (optimum value)

Example 2

Minimization Unbalanced Problem -Four new machines M1, M2, M3 and M3 are to be installed in a machine shop. There are five vacant places A, B, C, D and E available. Because of limited space, machine M2 cannot be placed at C and M3 cannot be placed at A. C_{ij} the assignment cost of machine I to place j. in rupees is shown below:

Table 5

	A	B	C	D	E
M1	4	6	10	5	6
M2	7	4	--	5	4
M3	--	6	9	6	2
M4	9	3	7	2	3

Find optimal assignment schedule

Solution

Adding dummy machine dummy

Table 6

	A	B	C	D	E
M1	4	6	10	5	6
M2	7	4	--	5	4
M3	--	6	9	6	2
M4	9	3	7	2	3
	0	0	0	0	0

Now implementing TLBO method on the problem i.e after applying teacher's phase and learner's phase we get,

-8	-4	-2	-6	-4
-2	**-3**	∞	-2	-3
∞	-4	-4	-4	**-11**
-4	-9	-4	**-11**	-9
-6	-6	**-6**	-6	-6

Minimum cost of machines = 4+4+2+2+0 = 12 rs.

Example 3

Maximization Problem: A company has a team of four salesmen and there are four districts where the company wants to start its buisnesss.

After taking into account the capabilities of salesmen and the nature of district, the company estimated that the profit per day in rupees for each salesman in each district as below.

Table 7

	1	2	3	4
A	16	10	14	11
B	14	11	15	15
C	15	15	13	12
D	13	12	14	15

Solution

Changing this maximization problem into minimization type, we get

Table 8

	1	**2**	**3**	**4**
A	0	6	2	5
B	2	5	1	1
C	1	1	3	4
D	3	4	2	1

Now implementing TLBO method on the problem i.e. after applying teacher's phase and learner's phase we get,

$$\begin{bmatrix} -10 & -4 & -6 & -4 \\ -5 & -3 & -7 & -7 \\ -6 & -6 & -3 & -3 \\ -3 & -3 & -4 & -6 \end{bmatrix}$$

Minimum profit per day = 16+15+15+14 = 60 rs.

Example 4

Minimization Problem: Four different jobs can be done on four different machines. The setup and take down time costs are assumed to be prohibitively high for changeovers. The matrix below gives the cost in rupees of producing job I on machine j.

5	7	11	6
8	5	9	6
4	7	10	7
10	4	8	3

How the jobs should be assigned to the various machine so that total cost is minimized. Also formulate the mathematical model for the problem.

Solution

Population

$$\begin{bmatrix} 5 & 7 & 11 & 6 \\ 8 & 5 & 9 & 6 \\ 4 & 7 & 10 & 7 \\ 10 & 4 & 8 & 3 \end{bmatrix}$$

On optimizing the problem with TLBO algorithm we get:

$$\begin{bmatrix} -9 & -3 & -3 & -7 \\ -3 & -7 & -3 & -4 \\ -10 & -4 & -4 & -4 \\ -5 & -10 & -5 & -12 \end{bmatrix}$$

Total minimized cost => 5+5+4+3=17 Rs.

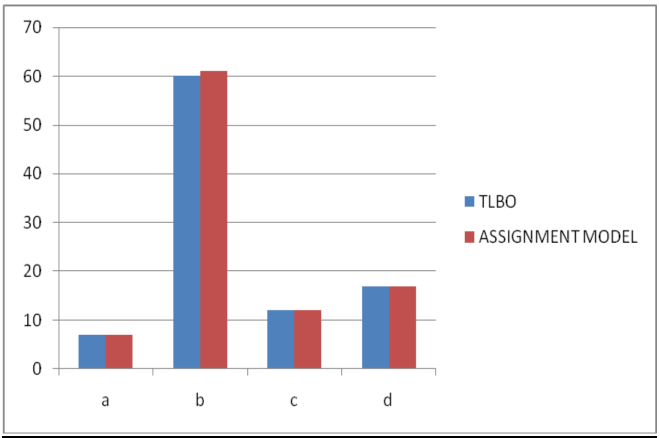

Figure 3: Comparison of TLBO with Assignment Model

CONCLUSIONS

All the nature-inspired algorithms such as GA, PSO, ACO, ABC, HS, etc. require algorithm parameters to be set for their proper working. Proper selection of parameters is essential for the searching of the optimum solution by these algorithms. A change in the algorithm parameters changes the effectiveness of the algorithms. To avoid this difficulty an optimization method, TLBO, which is algorithm parameter free, is presented in this paper. This method works on the effect of influence of a teacher on learners. Like other nature-inspired algorithms, TLBO is also a population based method which uses a population of solutions to proceed to the global solution. For TLBO, the population is considered as a group of learners or a class of learners. The process of working of TLBO is divided into two parts. The first part consists of 'Teacher Phase' and the second part consists of 'Learner Phase'. The 'Teacher Phase' means learning from the teacher and the 'Learner Phase' means learning through the interaction between learners.

In this work four assignment model, are considered for the process parameters optimization using new algorithms. The same models were earlier attempted using assignment model. The newly developed TLBO algorithm is successfully applied to all the four examples. In some cases TLBO has given the similar results to that of assignment model,but in all those cases, TLBO algorithem uses very small population size and less no. of oteration to converge the optimum result.but in some cases TLBO has reduced the confusion of assigning the job,over assignment model.thus, the TLBO algorithem is proved superior over the assignment model. In similar way, the TLBO can be effectively applied to Transportation model and sequencing model.

REFERENCES

1. Teaching–learning-based optimization: A novel method for constrained mechanical design optimization problems R.V. Rao, V.J. Savsani, D.P. Vakharia. © 2011 Elsevier Ltd.

2. Teaching–Learning-Based Optimization: An optimization method for continuous non- linear large scale problems R.V. Rao, V.J. Savsani, D.P. Vakharia 2012 Elsevier Inc.

3. Parameter optimization of machining processes using teaching–learning-based optimization algorithm P. J. Pawar & R. Venkata Rao , Springer-Verlag London 2012

4. Parameters optimization of advanced machining processes using TLBO algorithm R V Rao*1, V D Kalyankar EPPM, Singapore, 20-21 Sep 2011.

5. http://cacareer.weebly.com/uploads/2/0/4/0/2040831/assignment_problem.pdf

6. Non-conventional optimization techniques in optimizing non-traditional machining processes:A review Arindam Debroy and Shankar Chakraborty, 2013 Growing Science Ltd.
7. Goldberg D. Genetic algorithms in search, optimization, and machine learning.New York: Addison-Wesley; 1989.
8. Kennedy V, Eberhart R. Particle swarm optimization. In: Proceedings of the IEEE International Conference on Neural Networks. 1995. p. 1942–48.
9. Clerc M. Particle swarm optimization. ISTE Publishing Company; 2006
10. Karaboga D. An idea based on honey bee swarm for numerical optimization. Technical report-TR06. Erciyes University, Engineering Faculty, Computer Engineering Department. 2005.
11. Basturk B, Karaboga D. An artificial bee colony (ABC) algorithm for numeric function optimization. In: IEEE Swarm Intelligence Symposium. 2006.
12. Karaboga D, Basturk B. On the performance of artificial bee colony (ABC) algorithm. Applied Soft Computing 2008;8:687–97.
13. Lee KS, Geem ZW. A new meta-heuristic algorithm for continuous engineering optimization: harmony search theory and practice. Computer Methods in Applied Mechanics and Engineering 2004;194:3902–33.